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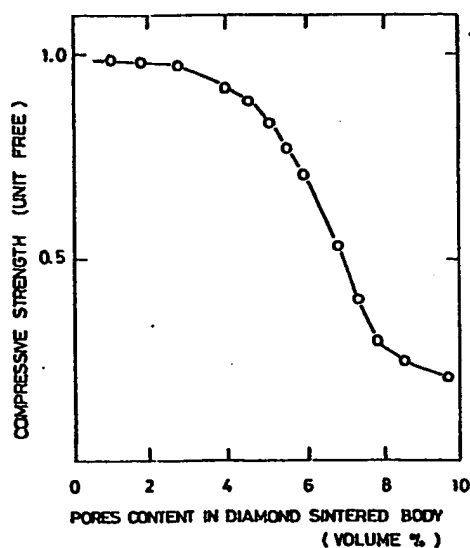
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(54) Diamond sintered body for tools and method of manufacturing the same.

(57) A diamond sintered body for tools contains a diamond content in excess of 93 percent and not more than 99 percent by volume and a residue including at least one of a metal or a carbide selected from groups IVa, Va and VIa of the periodic table and a ferrous metal of 0.1 to 3 percent by volume in total and pores at least 0.5 percent and not more than 7 percent by volume.

FIG.1



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Diamond Sintered Body for Tools and Method of  
Manufacturing the Same

BACKGROUND OF THE INVENTION

5 Field of Invention

The present invention relates to a diamond sintered body which is applied to various tools such as a cutting tool, a drill bit and a wiredrawing die, and a method of manufacturing the same.

10 Description of the Prior Art

Now on the market is a sintered body for tools containing a diamond content in excess of 70 percent by volume in which diamond particles are bonded to each other. Such a sintered body is employed for cutting  
15 nonferrous metals, plastics or ceramics, or applied to dressers, drill bits or wiredrawing dies. The diamond sintered body is remarkably excellent in efficiency particularly when the same is employed in cutting of nonferrous metals or applied to wiredrawing dies of  
20 relatively soft wire rods such as copper wires.

Such diamond sintered bodies are provided in various structures and shapes depending on application thereof, and the cutting tools, dressers and rock drilling bits are generally formed by those in which layers of diamond

sintered bodies are bonded to highly tough base metals such as cemented carbide.

Known as examples of compound sintered compacts in the aforementioned structure are a compound sintered compact disclosed in U.S. Patent No. 3745623 in which a layer of a diamond sintered body is directly bonded to a base material of WC-base cemented carbide and that disclosed in U.S. Patent No. 4403015 in which a layer of a diamond sintered body is bonded to a base material of cemented carbide etc. through an intermediate bonding layer.

In the diamond sintered body layer of the aforementioned compound sintered compact now in use, a ferrous metal such as cobalt is generally employed as a binder for diamond particles. The ferrous metal is utilized as a catalyst for synthesizing diamond from graphite, and is considered to partially dissolve the diamond powder in sintering under a superhigh pressure, thereby to securely sinter the layer of the diamond particles.

The ferrous metal may be mixed with the diamond powder before sintering, and also known in the art is a method of infiltrating a solution of the base material of WC-Co in the diamond powder in sintering, as disclosed in U.S. Patent No. 3745623. Such a diamond sintered body is

excellent in abrasion resistance and strength and highly efficient in a service for which single-crystal diamond has generally been employed, whereas the same is greatly restricted with respect to heat resistance. Diamond is  
5 graphitized from its surface under a temperature about 900°C and over in the atmosphere, while such graphitization is hardly caused in a vacuum or an inert gas even if the temperature is about 1400°C. However, when the aforementioned general diamond sintered body is  
10 heated, efficiency of the tool is deteriorated at a temperature of about 750°C. It means that the efficiency is naturally lowered under such a condition of use that the tool of, e.g., a cutting tool or drilling bit is used under a high temperature. The conventional diamond  
15 sintered body may be deteriorated at a temperature lower than that in the case of single-crystal diamond for the reason that the diamond is largely different in thermal expansion coefficient from the ferrous metal binder and the thermal stress in the sintered body is increased by  
20 heating whereby the texture is broken and that the ferrous metal facilitates graphitization of the diamond.

In order to improve heat resistance of the diamond sintered body, proposed is a method of preparing a sintered body which is not bonded to a base material such  
25 as cemented carbide and dipping the same in aqua regia or

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the like to be heated, thereby to leach the metallic bond phase in the sintered body, as disclosed in U.S. Patent No. 4224380. It is considered that heat resistance of the diamond sintered body is improved to stand heating up to  
5 1200°C.

In the diamond sintered body disclosed in U.S. Patent No. 4224380, about 8 percent by volume of pores are defined since the metallic bond phase is leached by acid treatment. Thus, strength of the sintered body is so  
10 greatly lowered that the same is not sufficient in toughness as a tool. In the method disclosed in the prior art, further, the sintered diamond body is not bonded to cemented carbide which improves its toughness, and hence the same is not satisfactory in application to a drilling  
15 bit.

The inventors have already proposed a diamond sintered body which is excellent in strength, abrasion resistance and heat resistance as disclosed in Japanese Patent Laying-open Gazette No. 35066/1984. The sintered  
20 body disclosed therein is obtained by employing a carbide selected from groups IVa, Va and VIa of the periodic table as the binder to substantially decrease content of pores thereby to prevent lowering of strength of the sintered body caused by leaching of cobalt.

5

However, it has been recognized that although the diamond sintered body disclosed in Japanese Patent Laying-open Gazette No. 35066/1984 is reliably prevented from lowering of strength, the same is deteriorated by difference in thermal expansion between the carbide and the diamond material under a high temperature over 1000°C. Thus, the diamond sintered body is not yet satisfactory in application to a tool whose edge is exposed to a high temperature such as that employed in geothermal well drilling.

#### SUMMARY OF THE INVENTION

Accordingly, an object of the present invention is to provide a diamond sintered body for tools which is further excellent in heat resistance, strength and abrasion resistance.

Provided according to a broad aspect of the present invention is a diamond sintered body which contains a diamond content in excess of 93 percent and not more than 99 percent by volume and a residue including 0.1 to 3 percent by volume of a metal or a carbide selected from groups IVa, Va and VIa of the periodic table and/or a ferrous metal and pores at least 0.5 percent and not more than 7 percent by volume or further including 0.005 to 0.25 percent by volume of boron and/or a boride.

The above and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is an illustration showing relation between compression strength and volume of pores in a heat-resistant diamond sintered body from which a bonding phase is leached;

Fig. 2 is an illustration showing relation between diamond particle size and flexure resistance in the diamond sintered body;

Fig. 3 is an illustration showing results of excavation of andesite by heat-resistant diamond sintered bodies obtained by Example 4; and

Fig. 4 is an illustration showing results of excavation of andesite by heat-resistant diamond sintered bodies obtained by Example 12.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

The inventors have studied deeply to obtain a diamond sintered body which is further excellent in heat resistance, and found that heat resistance is further improved with excellent abrasion resistance and strength in a diamond sintered body which contains a diamond

content in excess of 93 percent and not more than 99 percent by volume and a residue including 0.1 to 3 percent by volume of a metal or a carbide selected from groups IVa, Va and VIa of the periodic table and/or a ferrous metal and pores at least 0.5 percent and not more than 7 percent by volume or further including 0.005 to 0.25 percent by volume of boron and/or a boride.

As hereinabove described, the ferrous metal employed as the binder may be removed to improve heat resistance of the diamond sintered body. However, as the result, pores are defined by removal of the binder. Relation between strength of a diamond sintered body and the pores thus defined is as shown in Fig. 1. Namely, strength of the diamond sintered body is reduced as the content of the pores is increased, the said reduction beginning with the content of pores exceeding 3 percent with steep lowering with the said content within a range of 4.5 to 8 percent and reduction in the rate of lowering with the content of the pores in excess of 8 percent.

In general, strength required for a diamond sintered body depends on application thereof and strength of the substance to be worked. For example, strength half as much again as that of a commercially available heat-resistant diamond sintered body is sufficient to improve efficiency of a tool for drilling relatively soft



rocks and cutting ceramics. Therefore, at least the content of the pores must be not more than 7 percent by volume and the diamond sintered body must contain a diamond content in excess of 93 percent by volume in such application. If the content of the pores is less than 5 percent by volume, the strength of the diamond sintered body is over three times as much as that of the commercially available heat-resistant diamond sintered body, whereby efficiency of the diamond sintered body is improved to be preferable for drilling of hard rocks and cutting of hard ceramics.

In a method according to the present invention, obtained is a highly concentrated sintered body containing a diamond content in excess of 93 percent by volume by heating diamond powder material at a high temperature over 1300°C to graphitize the surface of the diamond powder, whose particles are different in size from each other. However, if the diamond content exceeds 99 percent by volume, strength of the diamond sintered body is rendered insufficient by shortage of content of a ferrous metal.

The diamond sintered body according to the present invention preferably includes smallest possible content of pores as shown in Fig. 1, whereas a ferrous metal is required to obtain a strong sintered body as hereinabove described. Therefore, the sintered body according to the

present invention contains at least 0.5 percent by volume of pores.

The inventors have studied deeply to obtain a diamond sintered body which is further excellent in heat.

5 resistance, and found that a diamond sintered body excellent in heat resistance and strength as hereinabove described is that contains 60 to 90 percent by volume of coarse diamond larger than  $3\mu\text{m}$  in particle size and a residue including 5 to 39 percent by volume of a binder  
10 and pores at least 1 percent and not more than 5 percent by volume, the binder including 60 to 95 percent by volume of superfine diamond smaller than  $1\mu\text{m}$  in particle size, 0.1 to 5 percent by volume of a carbide selected from groups IVa, Va and VIa of the periodic table and a ferrous  
15 metal not more than 10 percent by volume. In other words, the diamond sintered body according to the present invention contains coarse diamond larger than  $3\mu\text{m}$  in particle size and fine diamond smaller than  $1\mu\text{m}$  in particle size in the ratio of 60:38 to 90:6 in volume.

20 The diamond sintered body according to the present invention is obtained by sintering coarse diamond particles with a binder containing fine diamond particles. Thus, the binder is filled between the coarse diamond particles, whereby the sintered body contains considerable  
25 volume of diamond.

The diamond sintered body according to the present invention is considered to be excellent in toughness and abrasion resistance for the following reason:

As shown in Fig. 2, strength of a diamond sintered  
5 body is lowered with increase of the particle size. A  
diamond sintered body containing fine diamond particles is  
excellent in flexure resistance and toughness and hence  
the tip thereof is hard to be damaged, whereas the  
respective particles are retained by small diamond  
10 skeltons and bonding strength therebetween is weak. Thus,  
the respective diamond particles tend to fall during  
cutting operation, leading to inferiority in abrasion  
resistance.

On the other hand, the coarse diamond particles are  
15 retained by larger diamond skeltons with excellent bonding  
strength between the respective diamond particles and  
hence a diamond sintered body containing the coarse  
diamond particles is excellent in abrasion resistance,  
whereas cracking caused in the larger skelton portions  
20 tends to be propagated to damage the tip and deteriorate  
its toughness.

The diamond sintered body according to the present  
invention is obtained by sintering coarse diamond  
particles utilizing a binder containing fine diamond  
25 particles, and hence the diamond sintered body thus

obtained is considered to have excellent toughness of the fine diamond particles and excellent abrasion resistance of the coarse diamond particles.

The particle size of the coarse diamond contained in the diamond sintered body according to the present invention preferably exceeds  $3\mu\text{m}$ , since abrasion resistance is lowered if the said particle size is smaller than  $3\mu\text{m}$ . A diamond sintered body containing diamond particles in size of  $5\mu\text{m}$  to  $200\mu\text{m}$  is most excellent in both of toughness and abrasion resistance.

The coarse diamond powder material preferably contains 40 to 60 percent by volume of particles in average maximum particle size  $\underline{a}$ , 30 to 40 percent by volume of particles in particle size  $\underline{a}/2$  and a residue including particles in particle size  $\underline{a}/3$  to  $\underline{a}/1000$  for obtaining a diamond sintered body which contains a high concentration of diamond.

The content of the coarse diamond particles is preferably 60 to 90 percent by volume, since the content less than 60 percent by volume leads to lowered abrasion resistance while that exceeding 90 percent by volume leads to reduced diamond content of the diamond sintered body and lowered toughness.

The particle size of the superfine diamond employed as the binder is smaller than  $1\mu\text{m}$ , preferably smaller

than  $0.5\mu\text{m}$ , since the particle size exceeding  $1\mu\text{m}$  leads to lowered toughness of the diamond sintered body. The binder preferably contains 60 to 95 percent by volume of the superfine diamond particles, since the content of the  
5 superfine diamond particles less than 60 percent by volume leads to lowered abrasion resistance of the binder while that exceeding 95 percent by volume leads to lowered toughness of the binder.

The diamond sintered body according to the present  
10 invention contains diamond particles of various sizes, and if the diamond sintered body contains no metal nor carbide selected from groups IVa, Va and VIa of the periodic table, abnormal integration of the ferrous metal is caused particularly in the vicinity of fine diamond particles,  
15 thereby to define pores when the ferrous metal is leached. Therefore, strength of the diamond sintered body is further improved when the same contains a metal or a carbide. The diamond sintered body preferably contains 0.1 to 3 percent by volume of the ferrous metal and the  
20 metal or carbide selected from the groups IVa, Va and VIa of the periodic table. If the content exceeds 3 percent by volume, cracking may be caused by difference in thermal expansion between the same and the diamond whereby the diamond may be graphitized leading to lowering of heat  
25 resistance. Although the said content is preferably as

small as possible, at least 0.1 percent by volume of the ferrous metal etc. cannot be removed in practice.

It has been recognized that the diamond sintered body according to the present invention is particularly  
5 excellent in toughness, abrasion resistance and heat resistance when the carbide is prepared by tungsten carbide (WC) or molybdenum, tungsten carbide ((Mo,W)C) which is identical in crystal structure with tungsten carbide.

10 The diamond sintered body according to the present invention is further improved in characteristic when the same contains 0.005 to 0.25 percent by volume of boron or a boride or both of the same. In general, diamond powder is sintered by dissolution or precipitation of diamond  
15 material by a catalyst such as a ferrous metal under superhigh pressure/temperature. When at least one of the boron and the boride is added, a boride of the ferrous metal is produced to lower the melting point and increase the speed of dissolution/precipitation, whereby it may be  
20 supposed that bonded portions of diamond particles, i.e., diamond skeleton portions are grown to improve retaining force of the diamond particles. When the content of the boron or the boride is less than 0.005 percent, formation of the diamond skeleton portions is retarded. On the  
25 other hand, if the content of the boron or the boride

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exceeds 0.25 percent, considerable volume of boron enters the diamond skeleton portions to reduce the strength thereof.

The diamond powder material for manufacturing the  
5 diamond sintered body according to the present invention may be prepared by either of synthetic diamond and natural diamond.

In the method according to the present invention, powder prepared by diamond powder and particles of a  
10 carbide or a metal selected from groups IVa, Va and VIa of the periodic table and ferrous metal powder of iron (Fe), cobalt (Co) or nickel (Ni) with or without addition of boron or a boride are evenly mixed by a means such as a ball mill so that the diamond sintered body may contain  
15 the metal or carbide selected from the groups IVa, Va and VIa of the periodic table. The ferrous metal may not be mixed in the initial stage, and may be infiltrated in the powder material by bringing the powder material in contact with a ferrous metal member when the same is sintered.

20 Further, as disclosed in Japanese Patent Application Laying-Open No. 136015/1978 by the inventors, a pot and a ball for ball-mill operation may be prepared by a sintered body composed of a carbide selected from the groups IVa, Va and VIa of the periodic table and a ferrous metal to be  
25 mixed in, to pulverize the diamond powder by a ball mill

while introducing fine particles of the sintered body of the carbide selected from the groups IVa, Va and VIa of the periodic table and the ferrous metal from the pot and the ball.

5       The mixed powder is heated at a high temperature over 1300°C to partially graphitize the diamond material, and then introduced into a superhigh pressure/temperature apparatus to be sintered under a condition the diamond material is stable. The powder material must be sintered  
10 at a temperature higher than that of development of a eutectic liquid phase between the ferrous metal and the compound such as the carbide as employed. The diamond sintered body thus manufactured is introduced into an acid such as aqua regia which can corrode the ferrous metal,  
15 whereby the ferrous metal is removed to define the pores.

The diamond sintered body according to the present invention may be applied to a wiredrawing die, a ceramic cutting tool and a dresser etc. in addition to the drill bit.

20   Example 1

Diamond particles of 100  $\mu\text{m}$ , 50  $\mu\text{m}$ , 20  $\mu\text{m}$  and 5 to 0.2  $\mu\text{m}$  in average particle size were mixed in the ratio of 5:3:1:1, and the mixed diamond material was pulverized for 5 minutes utilizing a pot and a ball of WC-Co cemented  
25 carbide. The diamond powder thus obtained was heated at a



temperature of 1400°C for 30 minutes in a vacuum and filled in a vessel of molybdenum to be in contact with a plate of cobalt placed on the mixed powder, and subjected to a pressure of 55 kb and then heated at a temperature of 1460°C by a superhigh pressure/temperature apparatus, and retained in this state for 10 minutes.

The sintered body thus obtained was taken out from the vessel and subjected to chemical analysis. As the result, the sintered body contained 96.5 percent by volume of diamond, 0.15 percent by volume of tungsten carbide and 3.35 percent by volume of cobalt.

Then the sintered body was introduced into heated aqua regia to leach cobalt, and composition thereof was examined by a magnetic balance and by chemical analysis. As the result, the sintered body contained 96.5 percent by volume of diamond, 0.14 percent by volume of tungsten carbide, 0.4 percent by volume of cobalt and 2.96 percent by volume of pores. Compression strength of this sample was 380 Kg/mm<sup>2</sup>.

Another sample for comparison with the above was experimentally prepared by diamond particles having the same maximum particle sizes to the above so that this sample contained 92.0 percent by volume of diamond, 7.7 percent by volume of pores and 0.3 percent by volume of

cobalt. As the result, the compression strength of this sample for comparison was 120 Kg/mm<sup>2</sup>.

Then heat resistance of the sintered body according to the present invention was tested by heating the same at a temperature of 1200°C in a vacuum for 30 minutes. As the result, the sintered body presented no change in size or cracking.

#### Example 2

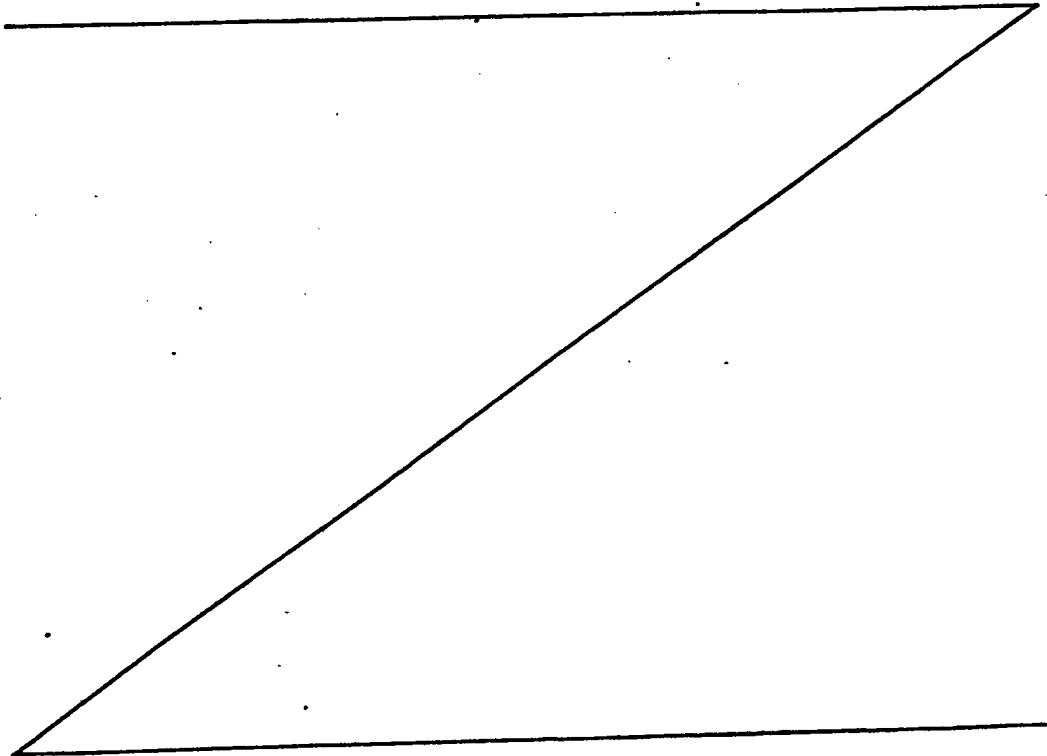
Diamond particles of 80  $\mu$ m, 40  $\mu$ m, 15  $\mu$ m and 0.5  $\mu$ m in average particle size were mixed in the ratio of 5:3:2:1. The diamond powder thus obtained was mixed with various ferrous metals and metals or carbides selected from the groups IVa, Va and VIa of the periodic table as shown in Table 1 to complete the diamond material, which was then filled in a vessel of tantalum (Ta) and sintered in a similar manner to Example 1 under a condition of 58 kb and 1500°C. The respective sintered bodies thus obtained were taken out from the vessel of tantalum to treat the same in heated aqua regia. Content of pores in each sintered body was then measured. The results are shown in Table 1.

Then each diamond sintered body was cut in the form of a cube having a side of 3 mm to be sintered and fixed by a high melting point/high hardness matrix of mixed powder of tungsten, tungsten carbide, iron, cobalt, nickel

and copper at a temperature of 1100°C, thereby to form a surface-set core bit.

Prepared for comparison therewith was a core bit formed by a commercially available sintered body of diamond particles of 40 to 60  $\mu$ m in particle size, which is shown by symbol X in Table 1, and a core bit formed by a sintered body of natural diamond, which is shown by symbol Y in Table 1.

Each of the samples A to L, X and Y as shown in Table 1 was adapted to drill graphite having uniaxial compression strength of 1600 to 2000 Kg/cm<sup>2</sup> by 900 r.p.m. The advancing speed and the life of each sample is shown in Table 2.



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Table 1

Sample	*1 Diamond Material	*1 Ferrous Metal	*1 *2 Carbide	*1 *3 *Pore
A	99.5	0.5Co		0.3
B	99.0	0.8Co	0.2WC	0.7
C	98.0	1.8Co	0.2WC	1.6
D	97.0	1.5Co, 1.0Ni	0.5 (MoW) C	2.3
E	96.0	3.7Co	0.3Tac	3.6
F	96.0	3.8Co	0.1TiC, 0.1NbC	3.5
G	96.0	3.0Co, 0.7Ni	0.2WC, 0.1HfC	3.5
H	96.0	3.7Co	0.3WC	3.6
I	95.0	5Co		4.7
J	95.0	5Co		1.0
K	95.0	4.5Co	0.5WC	4.4
L	93.0	6.5Co	0.5WC	6.2
X	Commercially Available Sintered Diamond			
Y	Natural Diamond			

\*1: Unit: volume %

\*2: Carbide of metal selected from groups IVa, Va and VIa of the periodic table

\*3: Volume of pores after acid treatment

Table 2

## Result of Granite Drilling

Sample	Advancing Speed (m/min)	Life (m)
A	10	1
B	15	over 50
C	18	"
D	20	"
E	18	"
F	17	"
G	18	"
H	16	"
I	15	"
J	cracked in formation of bit	
K	17	over 50
L	12	15
X	12	10
Y	5	45

Example 3

Diamond powder of  $0.8\ \mu\text{m}$  in average particle size and boron powder were pulverized and mixed by a pot and a ball of WC-Co cemented carbide. The mixed powder was mixed  
5 with diamond particles of  $60\ \mu\text{m}$ ,  $30\ \mu\text{m}$  and  $10\ \mu\text{m}$  in average particle size in the ratio of 1:5:3:1, and then heated at a temperature of  $1450^\circ\text{C}$  for one hour in a vacuum, and sintered in a similar manner to Example 1 under a condition of 55 kb and  $1450^\circ\text{C}$ . As the result of  
10 analysis, the sintered body thus obtained contained 96.2 percent by volume of diamond, 3.45 percent by volume of cobalt, 0.1 percent by volume of nickel, 0.2 percent by volume of tungsten carbide and 0.05 percent by volume of boron. The sintered body was then treated in heated aqua  
15 regia whereby 3.3 percent by volume of pores were defined.

The sintered body was adapted to cut an alumina ceramic member having Vickers hardness of 2300 at cutting speed of 60 m/min, depth of cut of 0.03 mm and feed rate of 0.05 mm/rev. employing a water-soluble cutting liquid  
20 for 15 minutes.

For comparison therewith, another alumina ceramic member was cut by a commercially available heat-resistant diamond material of  $40\ \mu\text{m}$  to  $60\ \mu\text{m}$  in particle size containing 8 percent by volume of pores.

As the result, the flank wear width of the sintered body according to the present invention was 0.15 mm, while that of the commercially available heat-resistant diamond material was 0.58 mm.

5 Example 4

Various diamond sintered bodies of 60  $\mu$ m in maximum particle size and different in diamond content from each other were prepared in a similar manner to Example 3 by varying the ratio of mixing of diamond particles varied in  
10 particle size and conditions of graphitization treatment, and then subjected to acid treatment to form heat-resistant diamond sintered bodies. Diamond content and pore content of each sintered body are shown in Table 3.

Table 3

Sample	Diamond Content (volume %)	Pore (volume %)	Metal plus Carbide (volume %)
M	96.8	2.8	0.4
N	95.1	4.6	0.3
O	94.3	5.5	0.2
P	93.0	6.8	0.2
Q	92.1	7.7	0.2
R	91.0	8.8	0.2

Each of the sintered bodies M to R as shown in Table 3 was processed as a blank for cutting work, which was adapted to cut andesite having compression strength of 1000 to 1100 Kg/cm<sup>2</sup> at cutting speed of 200 m/min, depth of cut of 1 mm and feed rate of 0.3 mm/rev. by a wet method for 20 minutes, to measure the flank wear width. The results are shown in Fig. 3.

As obvious from Fig. 3, the samples M, N, O and P, each containing pores of less than 7 percent by volume, are by far smaller in flank wear width than the samples Q and R which contain pores in excess of 7 percent by volume.

#### Example 5

Synthetic diamond powder of 1  $\mu$ m in particle size was pulverized by a pot and a ball of WC-Co cemented carbide. The powder thus obtained contained 91 percent by volume of fine diamond of 0.5  $\mu$ m in average particle size, 7 percent by volume of tungsten carbide and 2 percent by volume of cobalt. This powder was mixed with coarse diamond powder as shown in Table 4. The mixed powder was heated in a vacuum of 10<sup>-4</sup> Torr. at a temperature of 1500°C for 30 minutes and filled in a vessel of molybdenum to be in contact with a plate of cobalt placed on the completed powder, and subjected to a pressure of 55 kb by a superhigh pressure apparatus and then heated at a



temperature of 1450°C, and retained in this state for 15 minutes. The sintered body thus obtained was taken out from the vessel and dipped in heated aqua regia to leach cobalt. As the result of chemical analysis, the sintered  
5 body presented the composition as shown in Table 4. The diamond sintered body was heated at a temperature of 1200°C in a vacuum for 30 minutes, to measure strength thereof by a flexure test.

Measured for comparison was strength of diamond  
10 sintered bodies as shown in Table 4.

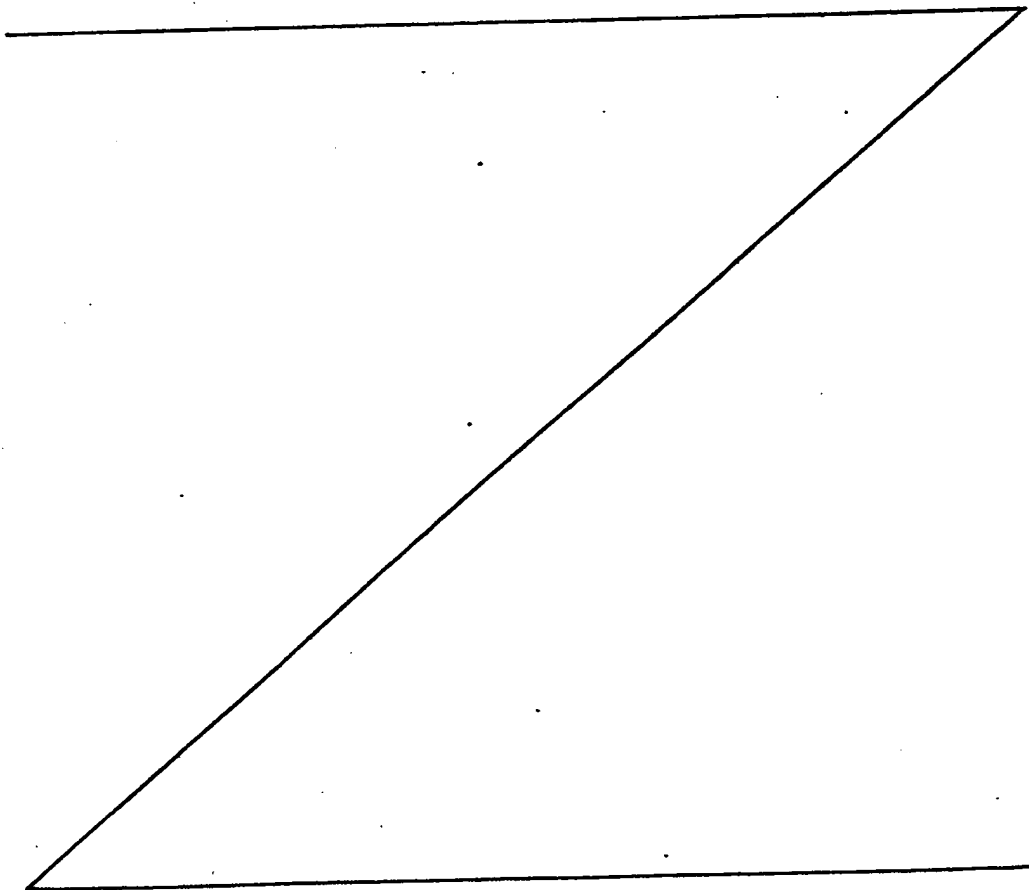


Table 4

No.	1	2	3	4	5	6	7	8	9	10	11	12
Mixing Ratio												
Coarse Diamond												
Coarse Diamond: Fine Diamond (volume ratio)												
Leaching of Ferros Metal												
Result of Analysis: Content of Co, Wc in Binder (%)												
Volume of Pores in Sintered Body												
Heating 1200°C x30 min.												
Strength												
(Kg/mm <sup>2</sup> )												
Diamond Content in Sintered Body (volume %)												

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Example 6

The diamond sintered bodies of sample Nos. 3, 7, 9 and 12 in Table 4 were processed to form tools for cutting. A reference tool was prepared for comparison by a commercially available diamond sintered body with leaching of cobalt and including pores of about 10 percent. The tools prepared by the samples Nos. 3, 7, 9 and 12 and the commercially available diamond sintered body were applied to cutting of granite in dry condition at a speed of 100 m/min. for 10 minutes. The results are as shown in Table 5.

Table 5

Sample No.	Result of Cutting (flank wear width mm)
3	0.56
7	tool worn upon cutting for 3 minutes, incapable of cutting
9	0.63
12	tool worn upon cutting for 1 minutes, incapable of cutting
Commercially Available Sintered Body	tool damaged upon cutting for 10 seconds

Example 7

Binder powder materials as shown in Table 6 were prepared with fine diamond of  $0.5\text{ }\mu\text{m}$  in average particle size. The binders were mixed with coarse diamond particles including diamond particles of  $80\text{ }\mu\text{m}$ ,  $40\text{ }\mu\text{m}$  and 5 to  $20\text{ }\mu\text{m}$  in the ratio of 6:3:1, in such ratios as shown in Table 7, to obtain completed powder material.

Table 6

Content (volume %)			
	Fine Diamond	Carbide of Groups IVa, Va, VIa of Periodic Table	Ferrous Metal
7A	91	6WC	3Co
7B	90	3 (Mo,W) C	7Co
7C	80	3WC; 1TiC	3Ni; 13Co
7D	60	1TaC; 2NbC; 2WC	20Co; 15Fe
7E	50	5WC	45Co
7F	80	10WC	10Co

Table 7

No.	Content of Coarse Diamond	Coarse Diamond: Fine Diamond (volume ratio)	Binder	Volume of Pores after Acid Treatment (%)	Flank Wear Width after Ceramic Cutting (mm)	Diamond Content in Sintered Body (%)
13	85	86.2 : 13.8	7A	0.3	0.53	98.5 %
14	70	72.2 : 27.8	7B	1.7	0.28	97.0 %
15	75	79 : 21	7C	2.2	0.55	95.0 %
16	90	93.75 : 6.25	7D	3.3	0.43	96.0 %
17	85	91.9 : 8.1	7E	6.5	0.89	92.2 %
18	95	95.5 : 4.5	7B	—	not completely sintered	99.0 %
19	60	62.5 : 37.5	7B	2.3	0.37	96.0 %
20	50	52.6 : 47.4	7B	2.8	0.65	95.0 %

Each completed powder material was processed in a vacuum at a temperature of 1450°C for one hour and filled in a vessel of molybdenum to be sintered under a superhigh pressure in a similar manner to Example 1, and the diamond sintered body thus obtained was taken out from the vessel and treated in heated aqua regia for 100 hours. The results are shown in Table 7 with the contents of pores in the sintered bodies after leaching of the ferrous metals. The sintered bodies were employed to form cutting tools for cutting alumina having Vickers hardness of 2000 at a speed of 80 m/min. in dry condition for 15 minutes, to examine heat resistance and strength. The results are also shown in Table 7.

#### Example 8

Diamond powder of 0.5  $\mu\text{m}$  in average particle size and powder of boron were pulverized and mixed by a pot and a ball of WC-Co cemented carbide. The mixed powder thus obtained contained 87 percent by volume of fine diamond of 0.3  $\mu\text{m}$  in average particle size, 4 percent by volume of tungsten carbide, 8 percent by volume of cobalt and 10 percent by volume of boron. This powder was mixed in the ratio of 15:85 with coarse diamond powder obtained by mixing diamond particles of 100 - 150  $\mu\text{m}$ , 50 - 80  $\mu\text{m}$  and 10 - 30  $\mu\text{m}$  in average particle size in the ratio of 55:30:15, to be processed in a vacuum at a temperature of

1400°C for one hour. Therefore, in this Example a volume ratio of coarse diamond to fine diamond was 86.7/13.3.

The completed powder thus obtained was filled in a vessel of molybdenum to be in contact with a plate of cobalt placed on the powder, and sintered in a similar manner to Example 5. The diamond sintered body thus obtained contained 0.1 percent by weight of boron.

Then the diamond sintered body was processed to form a column of 1.5 mm in diameter and 3 mm in length, to be treated in heated aqua regia for 150 hours. The diamond sintered body thus treated contained 2.5 percent by volume of pores and 97.3 percent by volume of diamond. The sintered body was sintered and fixed to a shank of steel by a high melting point/high hardness matrix of mixed powder of tungsten, tungsten carbide, iron, cobalt, nickel and copper at a temperature of 1100°C, to form a surface-set core bit.

Prepared for comparison therewith was a core bit formed by a commercially available sintered body of diamond particles of 40 to 60  $\mu$ m in particle size with leaching of a binder prepared by cobalt.

These core bits were tested to drill andesite having uniaxial compression strength of 180 Kg/mm<sup>2</sup> by 900 r.p.m.

As the result, the core bit formed by the diamond sintered body according to the present invention was still

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capable of drilling after drilling the andesite in 50 m at an advancing speed of 15 cm/min., while the life of the bit formed by the commercially available diamond sintered body ended upon drilling in 15 m at an advancing speed of 8 cm/min.

Description is now made on a compound type diamond sintered body obtained by directly or indirectly bonding the aforementioned diamond sintered body according to the present invention to a cemented carbide base material.

The compound type diamond sintered body comprises the above described diamond sintered body and a base material of cemented carbide, so that toughness of the cemented carbide is added to the diamond sintered body. Therefore, the compound type diamond sintered body is applicable to services such as cutting of hard ceramics and drilling of hard rocks in which high stress is applied to the tool.

When the diamond sintered body is directly bonded to cemented carbide, a layer rich in ferrous metal may be formed in the junction thereof whereby the ferrous metal in the said portion is leached in acid treatment to lower bonding strength. Therefore, the diamond sintered body is preferably bonded to the cemented carbide base material through an intermediate bonding layer formed by a cubic crystal type carbide, nitride or carbo-nitride selected from groups IVa, Va and VIa of the periodic table such as



that disclosed in U.S. Patent No. 4403015 thereby to prevent such corrosion and obtain a diamond sintered body excellent in bonding strength. Thickness of the intermediate bonding layer is preferably less than 0.5 mm, 5 since the intermediate bonding layer having thickness in excess of 0.5 mm is worn when the same is applied to the tip of a drilling bit or the like.

In the manufacturing method according to the present invention, the metal or carbide selected from groups IVa, 10 Va and VIa of the periodic table is added to the diamond sintered body by uniformly mixing diamond powder with the carbide or metal selected from the groups IVa, Va and VIa of the periodic table and powder of a ferrous metal such as iron, cobalt and nickel with or without addition of 15 boron or a boride by such means as a ball mill. The ferrous metal may not be mixed in the initial stage, but infiltrated in sintering by bringing the sintered body in contact with a member formed by the ferrous metal.

As disclosed in Japanese Patent Application 20 Laying-Open No. 136015/1978 by the inventors, a pot and a ball for ball-milling may be prepared by a sintered body of the carbide selected from the groups IVa, Va and VIa of the periodic table to be mixed in the diamond sintered body and a ferrous metal, thereby to simultaneously mix 25 fine powder of the sintered body formed by the carbide

selected from the groups IVa, Va and VIa of the periodic table and the ferrous metal in the diamond powder when the same is pulverized by the ball mill.

The mixed powder is heated at a high temperature over  
5 1300°C to partially graphitize the diamond material and filled in a vessel to be in contact with cemented carbide directly or through the intermediate bonding layer, and then the vessel is introduced into a superhigh pressure/temperature apparatus to be sintered under a  
10 condition the diamond material is stable and simultaneously bonded to the cemented carbide. The powder material must be sintered at a temperature higher than that of development of a eutectic liquid phase between the ferrous metal and the employed compound such as carbide.

15 The diamond sintered body obtained in the aforementioned manner is then treated by a liquid having an oxidation characteristic such as heated aqua regia, nitric acid or hydrofluoric acid. By such treatment in the liquid having the oxidation characteristic, the  
20 ferrous metal and the metal or carbide selected from the groups IVa, Va and VIa of the periodic table contained in the diamond sintered body can be leached. On the other hand, when the base material formed by cemented carbide is treated with the diamond sintered body in the liquid  
25 having the oxidation characteristic, an oxide film is

formed on the surface of the cemented carbide thereby to prevent leaching of the ferrous metal in the cemented carbide.

It is to be noted that only the diamond sintered  
5 layer may be dipped in the aforementioned liquid having the oxidation characteristic.

The diamond sintered body thus obtained can be applied to a cutting tool for working ceramics, a dresser and the like in addition to a drilling bit.

10 Example 9

Diamond particles of 80  $\mu\text{m}$ , 35  $\mu\text{m}$ , 20  $\mu\text{m}$  and 5 - 0.2  $\mu\text{m}$  in average particle size were mixed in the ratio of 45:35:1:1 and pulverized by a pot and a ball of WC-Co cemented carbide for 5 minutes. The powder thus obtained  
15 was heated in a vacuum at a temperature of 1400°C for 30 minutes. A WC-12%Co disc was coated by powder containing 60 percent by volume of cubic crystal type nitride boron and a residue including titanium nitride (TiN) and aluminum (Al) and introduced in a vessel of molybdenum.  
20 Then the aforementioned mixed powder was filled in the vessel to be in contact with a plate of cobalt which was placed on the completed powder, and introduced into a superhigh pressure/temperature apparatus to be subjected to a pressure of 55 kb and heated at a temperature of  
25 1460°C, and retained in this state for 10 minutes. The

sintered body thus obtained was taken out from the vessel, whereby observed was that the diamond sintered body was securely bonded to the cemented carbide base material through the intermediate bonding layer having the  
5 thickness of 0.5 mm.

Then, only the diamond sintered body was subjected to chemical analysis, to find that the same contained 96.0 percent by volume of diamond, 0.15 percent by volume of tungsten carbide and 3.85 percent by volume of cobalt.

10 Then the aforementioned diamond sintered body bonded to the cemented carbide base material through the intermediate bonding layer was dipped in heated aqua regia to be treated for 50 hours, whereby cobalt and tungsten carbide were partially leached from the diamond sintered  
15 body, which contained 96.0 percent by volume of diamond, 0.14 percent by volume of tungsten carbide, 0.8 percent by volume of cobalt and 3.06 percent by volume of pores, while only the surface of the cemented carbide base material was oxidized and substantially no cobalt was  
20 leached from the interior. Further, no corrosion of the intermediate bonding layer was observed.

The aforementioned substance was processed as a tool for cutting silicon nitride ( $\text{Si}_3\text{N}_4$ ) having Vickers hardness of 1800 at a cutting speed of 80 m/min., depth of

cut of 1 mm, feed rate of 0.1 mm/rev. in dry condition for 10 minutes.

Employed for comparison were a sintered body before aqua regia treatment and a commercially available heat-resistant diamond sintered body including 8 percent by volume of pores and not bonded to a base material of cemented carbide to cut trisilicon tetranitride under the same condition to the above.

As the result, the flank wear width of the diamond tip according to Example 9 was 0.15 mm while that of the tip with no leaching of cobalt was 0.35 mm. The commercially available diamond sintered body was damaged upon cutting for 30 seconds to be incapable of cutting.

#### Example 10

Diamond particles of 80  $\mu\text{m}$ , 40  $\mu\text{m}$ , 15  $\mu\text{m}$  and 0.5  $\mu\text{m}$  in average particle size were mixed in the ratio of 5:3:2:1. This powder was mixed with various ferrous metals and metals or carbides selected from the groups IVa, Va and VIa of the periodic table as shown in Table 8 to obtain completed powder materials. Then the completed powder materials were heated in a vacuum at a temperature of 1350°C to partially graphitize the diamond particles. An alloy of WC-15%Co was placed in a vessel of tantalum (Ta), on which the completed powder materials were filled to be sintered in a condition of 58 kb and 1500°C. The

respective sintered bodies thus obtained were taken out from the vessel of tantalum so that only the diamond sintered layers were dipped in an electrolytic solution to leach the ferrous metals from the diamond sintered bodies.

- 5        Also shown in Fig. 8 is the contents of pores in the diamond sintered bodies.

The respective diamond sintered bodies were brazed to bit bodies through base materials of cemented carbide, to form core bits.

- 10       Prepared for comparison were a surface-set core bit of natural diamond and a core bit of a diamond sintered body with no leaching of a ferrous metal.

- The respective samples were adapted to drill andesite having uniaxial compression strength of  $1600 - 1700 \text{ Kg/cm}^2$  by 500 r.p.m. Table 9 shows the advancing speed and the life of each sample.
- 15

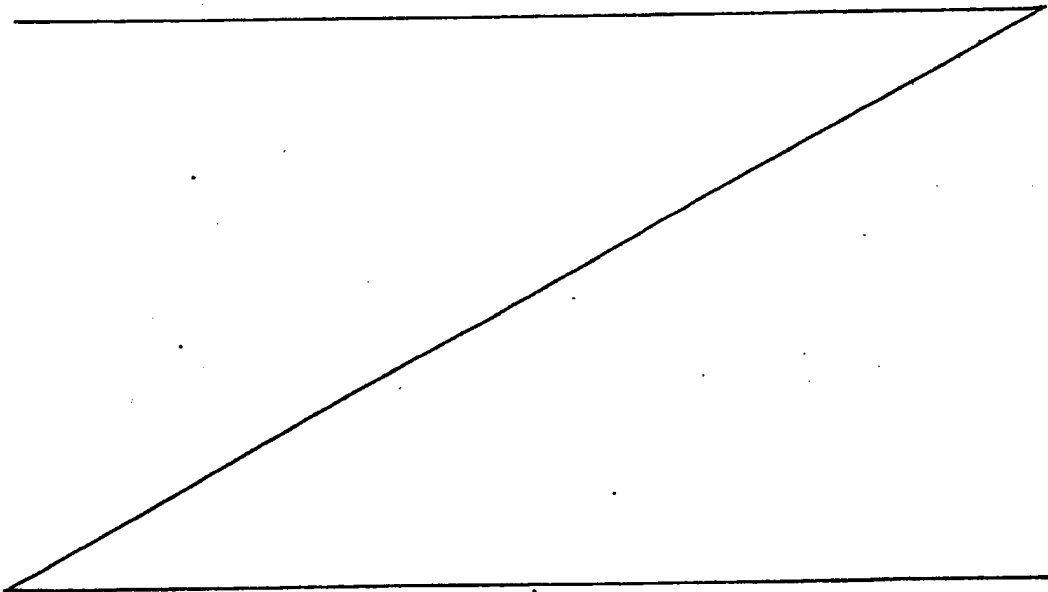


Table 8

Sample	*1 Diamond Material	*1 Ferrous Metal	*1 *2 Carbide	*1 *3 Pore
10A	99.5	0.5Co		0.2
10B	99.0	1.0Co		0.5
10C	98.0	1.8Co	0.2WC	1.4
10D	97.0	1.5Co, 1.0Ni	0.5 (MoW) C	2.1
10E	96.0	3.7Co	0.3Tac	3.3
10F	96.0	3.8Co	0.1TiC, 0.1NbC	3.2
10G	96.0	3.0Co, 0.7Ni	0.2WC, 0.1HfC	3.2
10H	96.0	3.7Co	0.3WC	3.3
10I	95.0	5Co		4.3
10J	95.0	5Co		0.8
10K	95.0	4.5Co	0.5WC	4.2
10L	93.0	6.5Co	0.5WC	6.0
10X	95.0	5Co		0
Y	Natural Diamond			

\*1: Unit: volume %

\*2: Carbide of metal selected from groups IVa, Va and VIa of the periodic table

\*3: Volume of pores after acid treatment

Table 9

## Result of Granite Drilling

Sample	Advancing Speed (cm/min)	Life (m)
10A	11	1.5
10B	16	over 80
10C	20	"
10D	21	"
10E	20	"
10F	18	"
10G	20	"
10H	17	"
10I	16	"
10J	12	"
10K	18	over 80
10L	14	30
10X	10	15
10Y	7	70

Example 11

Diamond powder of  $0.8\mu\text{m}$  in average particle size and powder of boron were pulverized and mixed by a pot and a ball of WC-Co cemented carbide. The powder material thus  
 5 obtained was mixed with diamond particles of  $50\mu\text{m}$ ,  $25\mu\text{m}$  and  $10\mu\text{m}$  in average size in the ratio of 1:5:3:1, to be



heated in a vacuum at a temperature of 1450°C for one hour and sintered under a condition of 55 kb and 1450°C in a similar manner to Example 9. Recognized by analysis was that the obtained diamond sintered body contained 96.0  
5 percent by volume of diamond, 3.65 percent by volume of cobalt, 0.1 percent by volume of nickel, 0.2 percent by volume of tungsten carbide and 0.05 percent by volume of boron. This diamond sintered body alone was treated in heated aqua regia, to define 3.4 percent by volume of  
10 pores.

The diamond sintered body was adapted to cut alumina ceramics having Vickers hardness of 2300 at a cutting speed of 80 m/min., depth of cut of 2 mm and feed rate of 0.1 mm/rev. for 15 minutes by employing water-soluble  
15 cutting liquid.

Prepared for comparison was a commercially available heat-resistant diamond material of 40 to 60  $\mu$ m in particle size containing 8 percent by volume of pores, which was not bonded to cemented carbide.

20 As the result, the flank wear width of the diamond sintered body according to the present invention was 0.25 mm while the commercially available heat-resistant diamond material was damaged after cutting for two minutes.

25 Example 12

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Heat-resistant diamond tips were prepared by changing mixing ratios and graphitizing process conditions of diamond particles in different particle sizes to form various diamond sintered bodies having the maximum particle size of 60  $\mu\text{m}$  and in various diamond contents in a similar manner to Example 11, with only the diamond sintered bodies being subjected to acid treatment. Table 10 shows the contents of diamond and pores of the respective diamond sintered bodies.

Table 10

Sample	Diamond Content (volume %)	Pores (volume %)	Metal + Carbide (volume %)
12M	97.1	2.5	0.4
12N	95.0	4.6	0.4
12O	94.5	5.2	0.3
12P	93.1	6.8	0.3
12Q	92.0	7.6	0.4
12R	91.0	8.8	0.2

10 The respective diamond sintered bodies 12M to 12R as shown in Table 10 were processed as tips for cutting andesite having uniaxial compression strength of 900 to 1000  $\text{Kg/cm}^2$  at a cutting speed of 150 m/min., depth of cut

of 2 mm and feed rate of 0.3 mm/rev., in dry condition for 20 minutes, to measure the flank wear width. The results are shown in Fig. 4.

As obvious from Fig. 4, the samples 12M, 12N, 12O and 5 12P respectively containing less than 7 percent by volume of pores are remarkably smaller in flank wear width than the samples 12Q and 12R respectively containing pores in excess of 7 percent by volume.

Although the present invention has been described and 10 illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of the present invention being limited only by the terms of the appended claims.

## WHAT IS CLAIMED IS:

1. A diamond sintered body for tools containing a diamond content in excess of 93 percent and not more than 99 percent by volume and a residue including at least one of a metal or a carbide selected from groups IVa, Va and VIa of the periodic table and a ferrous metal of 0.1 to 3 percent by volume in total and pores at least 0.5 percent and not more than 7 percent by volume.
2. A diamond sintered body for tools in accordance with claim 1, wherein said diamond content is in excess of 95 percent and not more than 99 percent by volume and said pores included in said residue is at least 0.5 percent and less than 5 percent by volume.
3. A diamond sintered body for tools in accordance with claim 1, wherein said diamond contained in said diamond sintered body contains coarse diamond larger than  $3\mu\text{m}$  in particle size and fine diamond smaller than  $1\mu\text{m}$  in particle size in the volume ratio of 60:38 to 90:6.
4. A diamond sintered body for tools in accordance with claim 3, wherein the particle size of said coarse diamond is at least  $5\mu\text{m}$  and not more than  $200\mu\text{m}$ .

5. A diamond sintered body for tools in accordance with claim 1, wherein said carbide selected from said groups IVa, Va and VIa of the periodic table is tungsten carbide (WC) or molybdenum tungsten carbide ((MoW)C) being  
5 identical in crystal structure with tungsten carbide.

6. A diamond sintered body for tools in accordance with claim 1, further containing at least one of boron and a boride of 0.005 to 0.25 percent by volume in total.

7. A compound diamond sintered body comprising a diamond sintered body for tools in accordance with claim 1 and a cemented carbide base material bonded to said diamond sintered body for tools.

8. A compound diamond sintered body in accordance with claim 7, wherein said diamond sintered body for tools and said cemented carbide base material are bonded to each other through an intermediate bonding layer.

9. A compound diamond sintered body comprising a diamond sintered body for tools in accordance with claim 6 and a cemented carbide base material bonded to said diamond sintered body for tools.

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10. A compound diamond sintered body in accordance with claim 9, wherein said diamond sintered body for tools and said cemented carbide base material are bonded to each other through an intermediate bonding layer.

11. A method of manufacturing a diamond sintered body for tools in accordance with claim 1, said method comprising the steps of:

preparing diamond powder or mixed powder of diamond  
5 powder and a metal or a carbide selected from groups IVa, Va and VIa of the periodic table and a ferrous metal;

graphitizing a part of diamond powder in said mixed powder at a temperature over 1300°C;

bringing said diamond powder in contact with a  
10 ferrous metal or a sintered carbide selected from said groups IVa, Va and VIa of the periodic table thereby forming a sintered body by performing hot press operation utilizing a superhigh pressure/temperature apparatus under a high temperature and a high pressure for retaining said  
15 diamond stable; and

subjecting said sintered body to acid treatment thereby to leach parts of said ferrous metal and said metal or carbide selected from said groups IVa, Va and VIa of the periodic table.

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12. A method of manufacturing a diamond sintered body for tools in accordance with claim 11, wherein said carbide selected from said groups IVa, Va and VIa of the periodic table is tungsten carbide or (molybdenum tungsten) carbide identical in crystal structure with tungsten carbide.

13. A method of manufacturing a compound diamond sintered body in accordance with claim 7, said method comprising the steps of:

preparing diamond powder or mixed powder of diamond powder and a metal or a carbide selected from groups IVa, Va and VIa of the periodic table and a ferrous metal; graphitizing a part of diamond in said mixed powder at a temperature over 1300°C; bringing said mixed powder in contact with a cemented carbide base material; bringing said mixed powder in contact with a ferrous metal or a sintered carbide selected from said groups IVa, Va and VIa of the periodic table to form a compound sintered body by employing a superhigh pressure/temperature apparatus under a high temperature and a high pressure for retaining said diamond stable; and treating said compound sintered body in an oxidation liquid thereby to leach parts of said ferrous metal and

said metal or carbide selected from said groups IVa, Va  
20 and VIa of the periodic table.

14. A method of manufacturing a compound diamond  
sintered body in accordance with claim 13, wherein said  
diamond mixed powder is brought into contact with said  
cemented carbide base material through an intermediate  
5 bonding layer.

15. A method of manufacturing a compound diamond  
sintered body in accordance with claim 13, wherein an  
oxide film layer is formed on the surface of said cemented  
carbide base material in said treatment thereby to prevent  
5 leaching of said ferrous metal in said cemented carbide  
base material by said oxidation liquid.

16. A method of manufacturing a diamond sintered  
body for tools in accordance with claim 1, said method  
comprising the steps of:

preparing mixed powder of diamond powder and a  
5 ferrous metal or of diamond powder, a metal or a carbide  
selected from groups IVa, Va and VIa of the periodic table  
and said ferrous metal;

graphitizing a part of said diamond in said mixed  
powder at a temperature over 1300°C;



10        forming a sintered body by performing hot press  
operation utilizing a superhigh pressure/temperature  
apparatus under a high temperature and a high pressure for  
retaining said diamond stable; and

          subjecting said sintered body to acid treatment  
15        thereby to leach a part of said ferrous metal or said  
metal or carbide selected from said groups IVa, Va and VIa  
of the periodic table.

          17. A method of manufacturing a diamond sintered  
body for tools in accordance with claim 16, wherein said  
carbide selected from said groups IVa, Va and VIa of the  
periodic table is tungsten carbide of molybdenum tungsten  
5        carbide identical in crystal structure with tungsten  
carbide.

          18. A method of manufacturing a compound diamond  
sintered body in accordance with claim 7, said method  
comprising the steps of:

          preparing mixed powder of diamond powder and a  
5        ferrous metal or of diamond powder, a metal or a carbide  
selected from groups IVa, Va and VIa of the periodic table  
and said ferrous metal;

          graphitizing a part of said diamond in said mixed  
powder at a temperature over 1300°C;

- 10 bringing said diamond into contact with a cemented  
carbide base material and forming a sintered body by  
performing hot press operation utilizing a superhigh  
pressure/temperature apparatus under a high temperature  
and a high pressure for retaining said diamond stable; and  
15 treating obtained said sintered body by an oxidation  
liquid to leach a part of said ferrous metal or said metal  
or carbide selected from said groups IVa, Va and VIa of  
the periodic table.

19. A method of manufacturing a compound diamond  
sintered body in accordance with claim 18, wherein said  
diamond is brought into contact with said cemented carbide  
base material through an intermediate bonding layer.

20. A method of manufacturing a compound diamond  
sintered body in accordance with claim 18, further  
comprising a step of forming an oxide film layer on the  
surface of said cemented carbide base material in  
5 treatment by said oxidation liquid.

21. A method of manufacturing a diamond sintered  
body for tools in accordance with claim 7, said method  
comprising the steps of:

preparing mixed powder of diamond powder and boron or  
5 a boride or of diamond powder and a metal or a carbide  
selected from groups IVa, Va and VIa of the periodic  
table, a ferrous metal and said boron or boride;

graphitizing a part of diamond in said mixed powder  
at a temperature over 1300°C;

10 forming a sintered body by bringing said powder in  
contact with a ferrous metal or a sintered carbide  
selected from said groups IVa, Va and VIa of the periodic  
table and performing hot press operation utilizing a  
superhigh pressure/temperature apparatus under a high  
15 temperature and a high pressure for retaining said diamond  
stable; and

subjecting said sintered body to acid treatment  
thereby to leach parts of said ferrous metal, said metal  
or carbide selected from said groups IVa, Va and VIa of  
20 the periodic table and said at least one of said boron and  
boride.

22. A method of manufacturing a diamond sintered  
body for tools in accordance with claim 21, wherein said  
carbide selected from said groups IVa, Va and VIa of the  
periodic table is tungsten carbide or molybdenum tungsten  
5 carbide identical in crystal structure with tungsten  
carbide.

23. A method of manufacturing a compound diamond sintered body in accordance with claim 9, said method comprising the steps of:

preparing mixed powder of diamond powder and boron or  
5 a boride or of diamond powder and a metal or a carbide selected from groups IVa, Va and VIa of the periodic table, a ferrous metal or a boride;

graphitizing a part of diamond in said mixed powder at a temperature over 1300°C;

10 bringing said diamond in contact with a cemented carbide base material, placing a ferrous metal or a sintered carbide selected from groups IVa, Va and VIa of the periodic table on said diamond to be in contact therewith and performing hot press operation utilizing a  
15 superhigh pressure/temperature apparatus under a high temperature and a high pressure for retaining said diamond stable to form a sintered body; and

treating said sintered body by an oxidation liquid to leach parts of said ferrous metal and said metal or  
20 carbide selected from said groups IVa, Va and VIa of the periodic table.

24. A method of manufacturing a compound diamond sintered body in accordance with claim 23, wherein

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said diamond is brought into contact with said cemented carbide base material through an intermediate bonding layer.

25. A method of manufacturing a compound diamond sintered body in accordance with claim 23, further comprising a step of forming an oxide film layer on the surface of said cemented carbide base material in treatment by said oxidation liquid.

26. A method of manufacturing a diamond sintered body for tools in accordance with claim 7, said method comprising the steps of:

preparing mixed powder of diamond powder, a ferrous metal and at least one of boron and a boride or of diamond powder, a metal or a carbide selected from groups IVa, Va and VIa of the periodic table, a ferrous metal and at least one of said boron and boride;

graphitizing a part of said diamond powder in the mixed powder at a temperature over 1300°C;

forming a sintered body by performing hot press operation utilizing a superhigh pressure/temperature apparatus under a high temperature and a high pressure for retaining said diamond stable; and

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15       subjecting said sintered body to acid treatment  
thereby to leach parts of said ferrous metal, said metal  
or carbide selected from said groups IVa, Va and VIa of  
the periodic table and said at least one of said boron and  
boride.

27. A method of manufacturing a diamond sintered  
body for tools in accordance with claim 26, wherein said  
carbide selected from said groups IVa, Va and VIa of the  
periodic table is tungsten carbide or molybdenum tungsten  
5 carbide identical in crystal structure with tungsten  
carbide.

28. A method of manufacturing a compound diamond  
sintered body in accordance with claim 9, said method  
comprising the steps of:

preparing mixed powder of diamond powder, a ferrous  
5 metal and at least one of boron and a boride or of diamond  
powder, a metal or a carbide selected from groups IVa, Va  
and VIa of the periodic table, a ferrous metal and at  
least one of said boron and boride;

graphitizing a part of said diamond powder in the  
10 mixed powder at a temperature over 1300°C;

forming a sintered body by performing hot press  
operation utilizing a superhigh pressure/temperature

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apparatus under a high temperature and a high pressure for retaining said diamond stable by bringing said mixed  
15 powder in contact with cemented carbide; and

treating said sintered body by an oxidation liquid to leach parts of said ferrous metal and said metal or carbide selected from said groups IVa, Va and VIa of the periodic table.

29. A method of manufacturing a compound diamond sintered body in accordance with claim 28, wherein said diamond is brought into contact with said cemented carbide base material through an intermediate bonding  
5 layer.

30. A method of manufacturing a compound diamond sintered body in accordance with claim 28, wherein an oxide film layer is formed on the surface of said cemented carbide base material in said treatment thereby to prevent  
5 leaching of said ferrous metal in said cemented carbide base material by said oxidation liquid.

31. A method of manufacturing a diamond sintered body for tools in accordance with claim 3, said method comprising the steps of preparing mixed powder of diamond powder larger than  $3\mu\text{m}$  in particle size, superfine

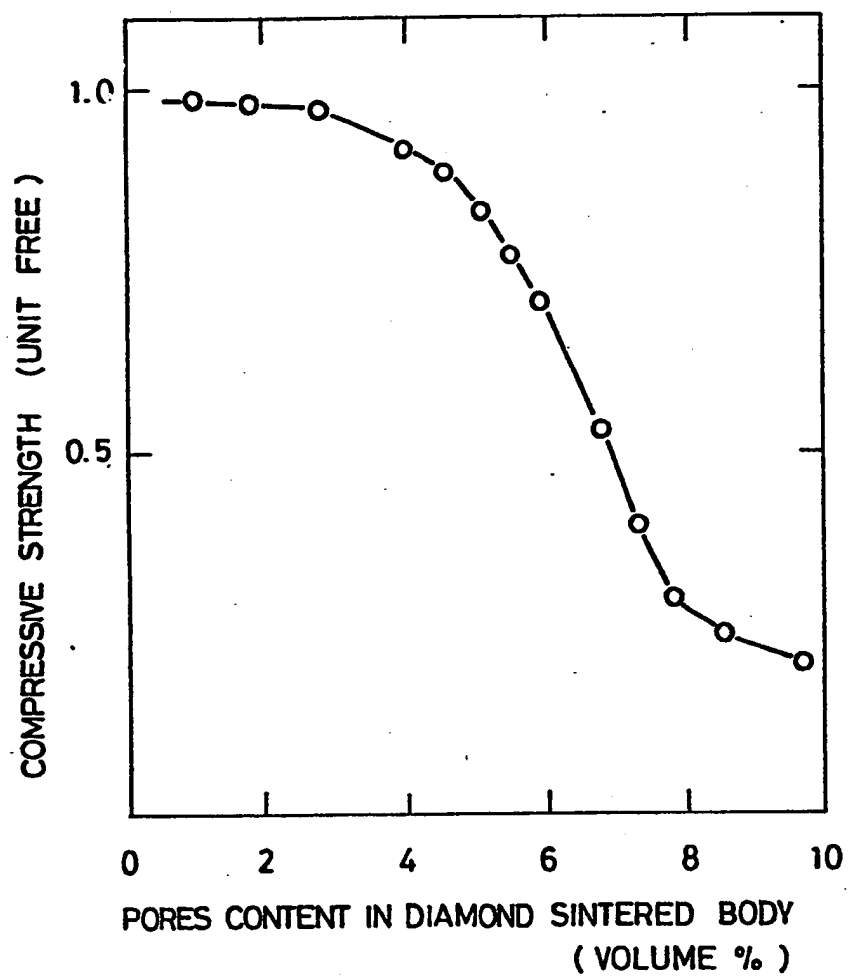
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- 5 diamond powder smaller than  $1\mu\text{m}$  in particle size, a carbide smaller than  $1\mu\text{m}$  selected from groups IVa, Va and VIa of the periodic table and a ferrous metal, graphitizing a part of the powder material at a temperature over  $1300^{\circ}\text{C}$ , performing hot press operation
- 10 utilizing a superhigh pressure/temperature apparatus under a high temperature and a high pressure for retaining said diamond stable and subjecting said sintered body to acid treatment thereby to leach a part of said ferrous metal.

32. A method of manufacturing a diamond sintered body for tools in accordance with claim 6, said method comprising the steps of preparing mixed powder of diamond powder larger than  $3\mu\text{m}$  in particle size, superfine
- 5 diamond powder smaller than  $1\mu\text{m}$  in particle size, a carbide smaller than  $1\mu\text{m}$  selected from groups IVa, Va and VIa of the periodic table and a ferrous metal, graphitizing a part of the powder material at a temperature over  $1300^{\circ}\text{C}$ , performing hot press operation
- 10 utilizing a superhigh pressure/temperature apparatus under a high temperature and a high pressure for retaining said diamond stable and subjecting said sintered body to acid treatment thereby to leach a part of said ferrous metal.



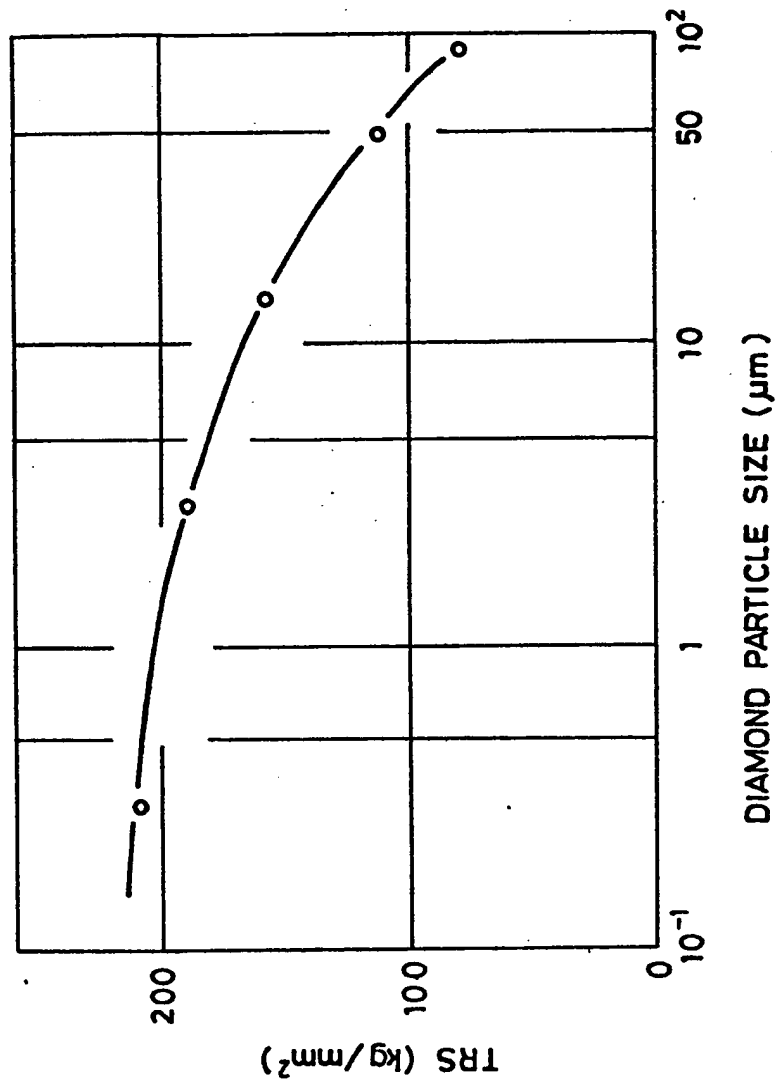
FIG. 1



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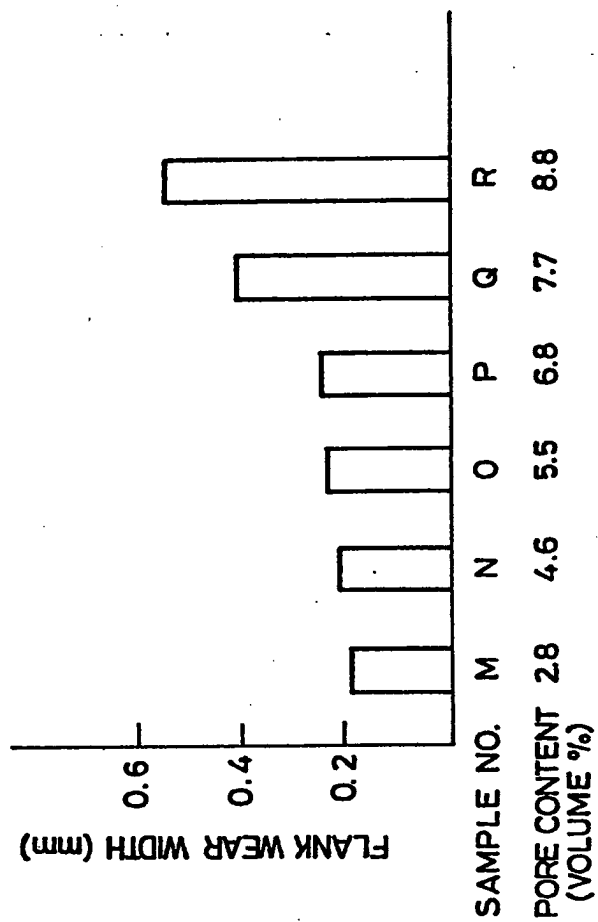
FIG.2



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FIG. 3



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FIG. 4

